TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 922

THE BREDA WIND TUNNEL

By Mario Pittoni

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The increasing importance of wind-tunnel tests on the practical design of aircraft has prompted the Breda company to equip its design section with a wind tunnel.

The purpose of a tunnel is to reproduce, in order of magnitude, the exact minimum C_D and, in addition, to inquire into the various components constituting an airplane and so effect the most suitable design measures for the fixed and moving parts, the increments of drag due to installation of armament, the best type and location of the radiator, etc.

A tunnel designed for such a program - which in a sense removes it from the purely scientific into the more practical field - must, above all, have a high operating speed, at least with the normal dimensions of the jet.

On this basis, the final choice fell on a 2-meter throat diameter, and a 310-kilometer-per-hour velocity. The power required for the operation of the tunnel was established from Tollmien's theory (reference 1) since, as is known, for the open-jet type, power dissipation along the closed circuit approaches that in the test chamber, due to the mingling and deflection of parts of the jet with the surrounding calm fluid and the consequent diminishing of the lift.

The exit cone taper was that of the Göttingen wind tunnel:

$$\tan \alpha = 0.1724; \quad \alpha = 9^\circ 47'$$

where α is the angle of the tunnel axis with the generatrice of the trunk of the cone, which separates the quiet from the disturbed zone. The other two trunks of the cone, having as base the mouth of the entrance cone enveloping

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*"La galleria del vento dell'Aeronautica Breda." Extract from "Auto Moto Avio," no. 5, March 1939, pp. 3-8.

the zone of uniform speed and that of equal lift, were plotted on the same theory.

Provisions were made for an air speed of 86 meters per second, and for 0.8 propeller efficiency, with a 725 horsepower (energy ratio = 2.3).

The design specifications called for:

Single-return passage with open jet;

Diameter of exit cone, 2 meters;

Maximum speed of jet attained - without protecting screen fitted, 100 m/s = 360 km/h;

Maximum speed in prolonged tests, 92 m/s = ~ 330 km/h;

At 92 m/s, 800 hp., propeller pitch 16, 2,100 r.p.m. (propeller r.p.m., 1,157), energy ratio, 2.55.

It is pointed out that, owing to the difficulty of knowing the exact power, the energy ratio is merely indicative.

The Breda tunnel was, as previously stated, built with a view to its eminently industrial application (fig. 1). This does not preclude its adaptation in the scientific field of future developments, in jet dimension, speed, or wind velocity.

The tunnel is of the open-throat, single-return type (fig. 2) with Prandtl-type circular and planimetric sections. The various sections are disposed at right angles for an over-all length of 38.40 meters. The whole tunnel, with the exception of the entrance cone and the entrance of the exit cone, is of reinforced concrete.

The concrete shell is 8 centimeters thick and, besides the rings at the four corners, is supported by similar rings at the connecting flanges of that part of the return circuit which is easily transportable and therefore mounted on a suitable carriage and rails.

Within the first concrete wall is another thinner wall (2.5 cm), with polished and carefully varnished surface. The base of reinforced concrete rests on a gravel foundation. The discharge opening of the entrance cone has a 2-meter diameter. Made of welded steel, it terminates in a perfectly cylindrical steel ring 12.5 centimeters wide, with fluted spout (fig. 3).

The wind tunnel has a constant diameter of 4.550 meters from the last corner to the beginning of the entrance cone. The contraction between the maximum section (12.26 m²) and the mouth of the exit (3.1416 m²) covers a length of 2.70 meters, as shown on figure 4.

The entrance mouth is fitted with a regulating ring incorporating 44 excess lift discharging orifices of 125-millimeter diameter (fig. 5). From these orifices to the plane of the first propeller, the tunnel section tapers 50 millimeters. Over a length of 18.61 meters, the section expands from 6.03 m² to 16.26 m².

The four corners of the circuit are fitted with vertical guide vanes (figs. 6, 7, and 8) of different sizes and chords. In the three corners following the fan, the vanes have a longer chord (c = 1,060 mm); 7, 8, and 10 in consecutive numbers. In the last corner the vanes are narrower (c = 742 mm) and thicker, and reach the number of 16. They are made of walnut with protected leading and trailing edges; doped with nitrocellulose, and fastened to steel fittings set in the cement.

The installation of these vanes necessitated the exact determination of the line of intersection of the profile of the vane with the inside tunnel wall. This was achieved with the jig shown in figure 9.

The cellular straightener (fig. 10) located in the cylindrical zone preceding the entrance cone, and 3.340 meters from the mouth of the latter, is made up of 5/10 gage steel tubes of 120-millimeter diameter and 400-millimeter length, with perfectly horizontal axis and irregularly arranged in the vertical plane. The whole is spot-welded.

Power Plant

The power plant consists of an 18-cylinder W-type Isotta Fraschini engine, type 18, R (800 hp. at 2,100 r.p.m.) with 0.551 gear ratio actuating a fan with double impeller.

The engine (fig. 11) is mounted on two wooden stringers (one on each side), and can be shifted longitudinally by about 0.700 meter.

The exhaust pipes open into three suction hoods which, with their concealed channels, form the head of the exhaust-gas outlet system.

A 5.5-horsepower electric motor actuates the group. The radiators and oil coolers located next to the engine are controlled from the engine-control panel (fig. 12) which contains, in addition to the conventional manometers and distant-reading thermometers, the gas throttle, the electric switches for the starting magneto, and the blower. Also, there is the compressed-air valve for starting and for the fire extinguisher for the three engine carburetors.

The engine crankshaft is coupled to an elastic coupling which in turn forms the first support of the transmission shaft. The second support, lodged inside the nacelle and 4.765 meters distant from the first, forms the hub of the countervanes.

The internal combustion engine was chosen for contingent rather than technical reasons, although it should be pointed out that the fluctuations in the voltage and the frequency in the electric power supply of the factory, have acted as a deterrent to the use of both the three-phase asynchronous motor and the synchronous motor with variable pitch propeller.

On the other hand, with the power available (about 600 kw.), a transformer cabin and a converter group with Léonard control would have meant an additional but unnecessary expense in the face of the industrial purposes for which the tunnel was designed. The fear of excessive jet turbulence arising from the use of an internal combustion engine has prompted an almost exaggerated care in design - ultimately resulting in an assembly in which the jet at the very first tests with wires and pitot tube, practically exceeded the most optimistic expectations.

Once the tunnel had reached a given speed, which was carefully kept constant for a certain throttle setting, the exploration wires were kept much steadier by gradually approaching the operating speed.

Future sphere tests will tell the tunnel turbulence.

The propeller assembly (fig. 13) (supplied by the Leonardo da Vinci Society) comprises two 8-blade impellers. The first has a diameter of 2.820 meters; the second, a diameter of 2.860 meters, with a clearance of 0.700 meter. The pitch of the 16 blades is variable simultaneously, with remote control and 32°40' maximum setting.

The handwheel for changing the pitch setting is connected to a dial with 28 divisions, each of which corresponds to 1° 10'.

At zero the blade tip has a negative setting (-2° 30') and the propeller thrust is practically zero. To neutralize the component of the rotary velocity induced by the air of the first propeller, it is followed by a radial straightener. The whole supporting framework of faired steel tubing with reinforced concrete base is entirely independent of the tunnel, so as to avoid reciprocal transmission of vibrations between propeller and tunnel.

The propeller shaft is mounted on two ball bearings, one of which also resists the axial propeller thrust. The propeller blades are of wood, fabric-covered and fastened by steel sleeves to the hub.

The rated propeller speed is 800 r.p.m. (engine speed 1,450 r.p.m.);

Maximum speed, 1,200 r.p.m. (engine speed, 2,178 r.p.m.);

The spinners provided at each end of the propellers have a maximum diameter of 700 millimeters.

The distance of the tip of the spinner from the plane of the first propeller is 0.880 meter. The rear spinner becomes the diameter of the transmission shaft (0.270 m) at 0.960 meter from the plane of the second propeller. Taking account of the 0.700-meter distance between propellers, gives 2.540 meters from the tip of the spinner to the base of the rear spinner.

The Balance

The balance now installed (fig. 14) is of the Toussain wire type, designed to record the lift, drag, rolling and pitching moment. It can be adjusted longitudinally, laterally, and vertically. We say "now installed," because this is to be supplemented by a six-component balance, mounted over the working section. The Toussain wire balance, although very sensitive and accurate, is not large enough for the velocity of the jet nor for the eventual maximum size of the models.

This does not prevent, however, its use for lift and drag tests, since only in those cases where the model is supported independently, is it desired to obtain the action of the resultant with respect to a point of the model itself. (For example, the moments due to vertical and horizontal surfaces for models pivoted in correspondence with the center of gravity.) In view of the last consideration, the longitudinal displacement of the balance is sufficient.

Adjoining the wind tunnel are the model-exhibit room (fig. 15) and the pattern shop. The ultimate enlargement of the plant is also indicated in figure 2.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

REFERENCE

1. Tollmien, W.: Berechnung turbulenter Ausbreitungvorgänge. Z.f.a.M.M., 1926.

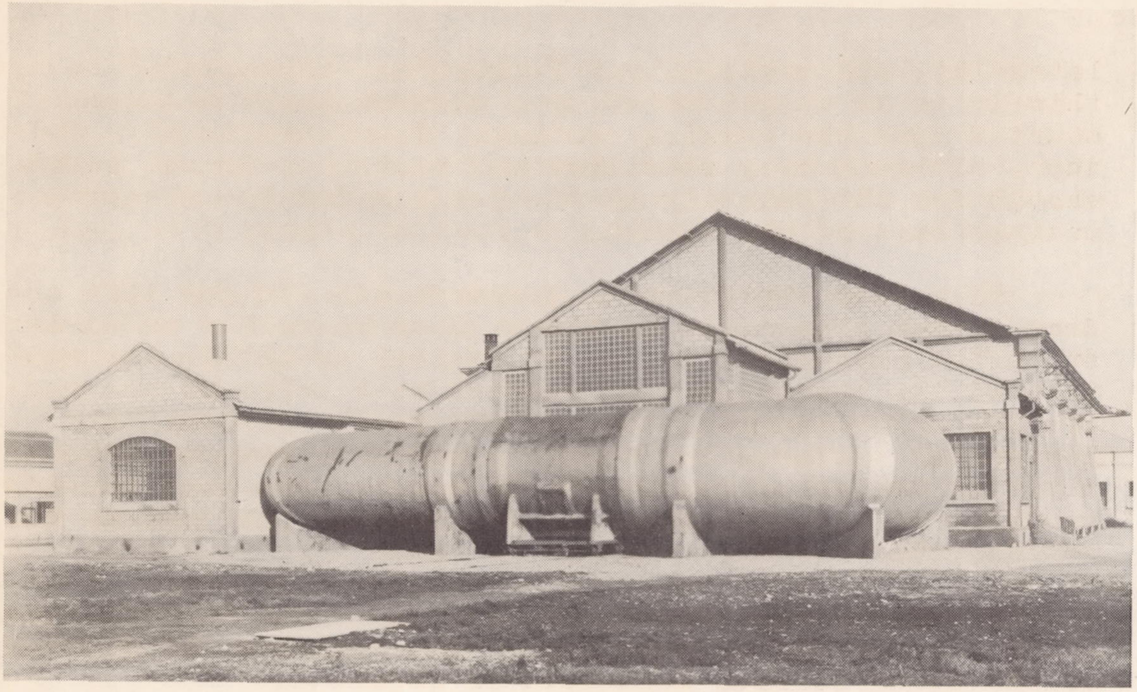

Figure 1.- External view of laboratory(Feb. 1939).

Figure 15.- View of model room.

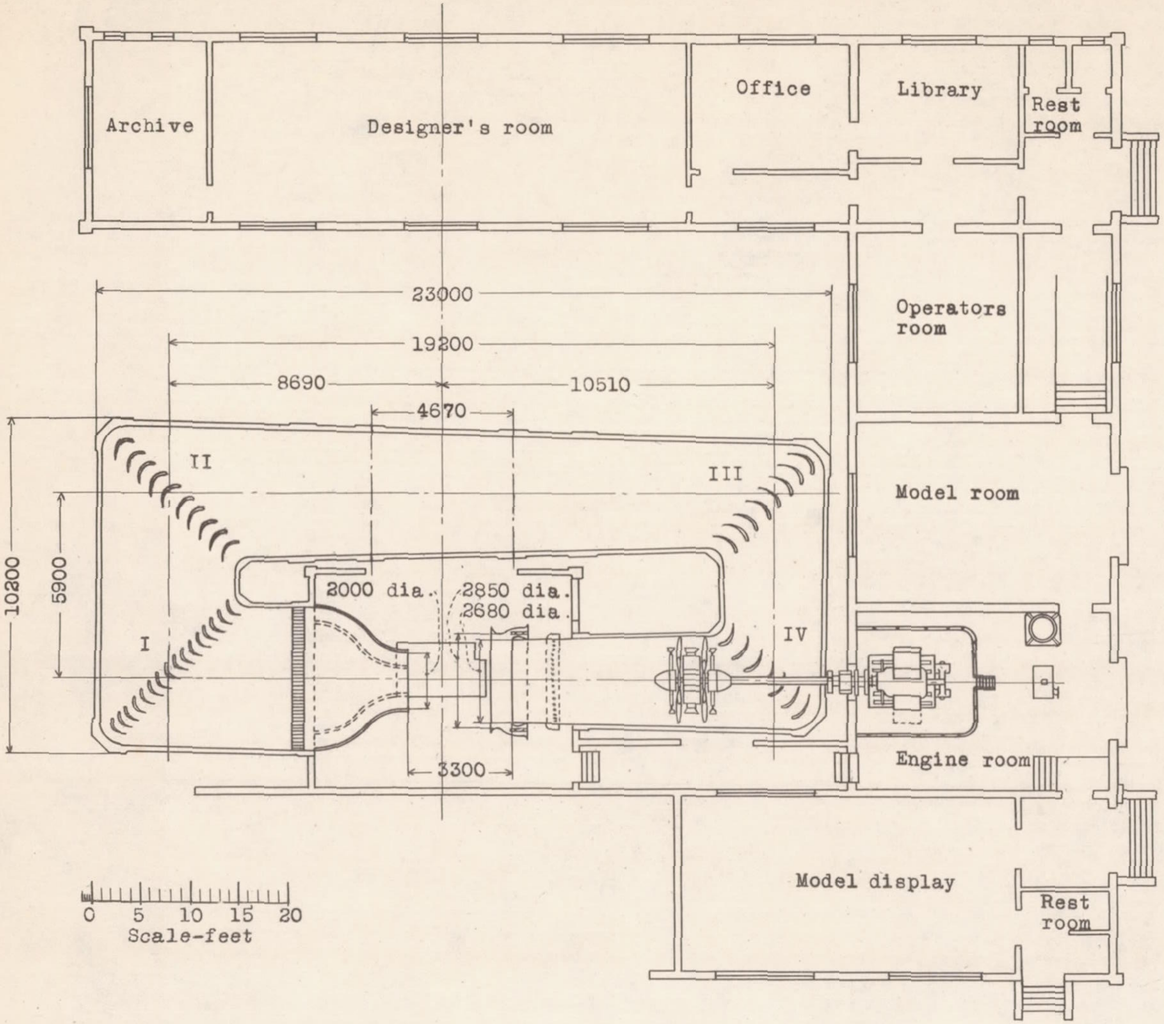

Figure 2.- General plan showing provisions for future expansion.

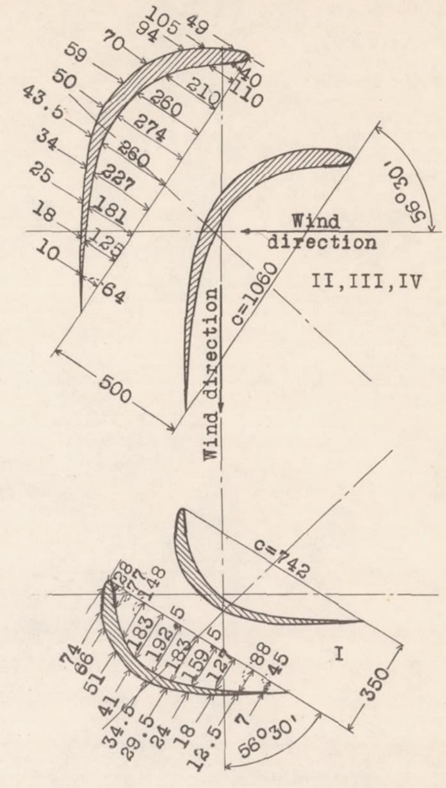

Figure 8.- Guide vanes with 1060 mm chord mounted in corners II,III, and IV as follows; 10 in corner II, 8 in corner III, 7 in corner IV. Guide vanes of 742 mm chord amounting to 16 are fitted in corner I.

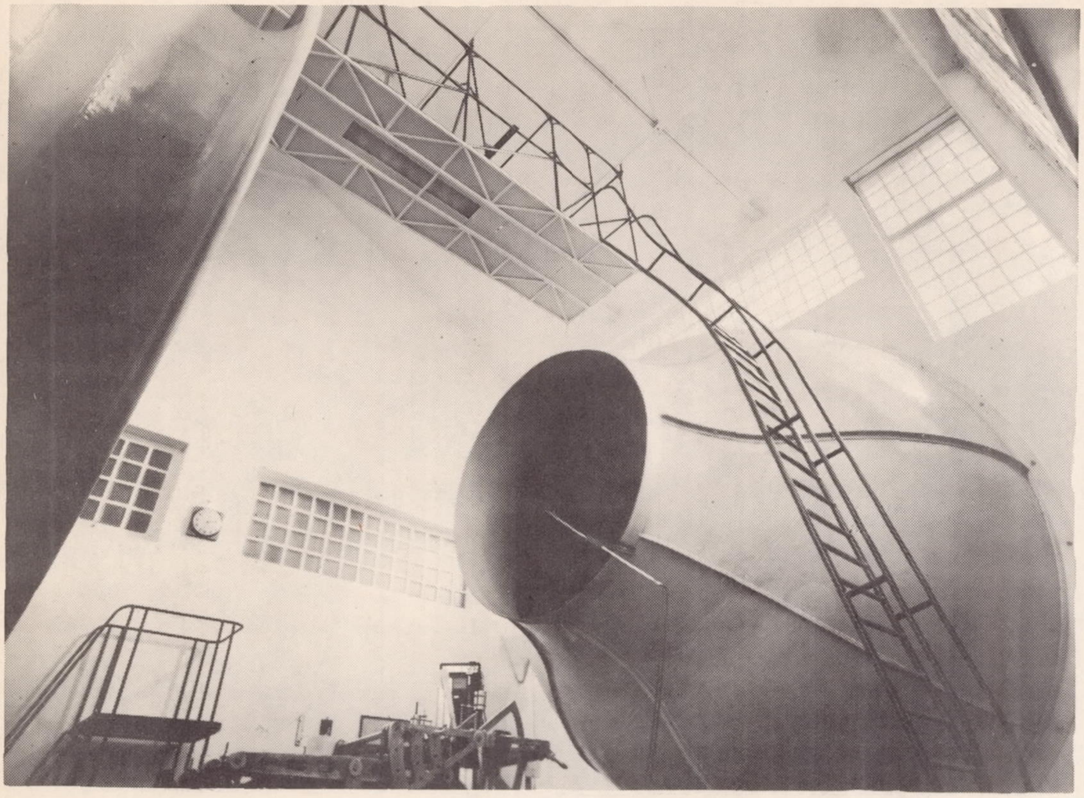

Figure 3.- Entrance cone.

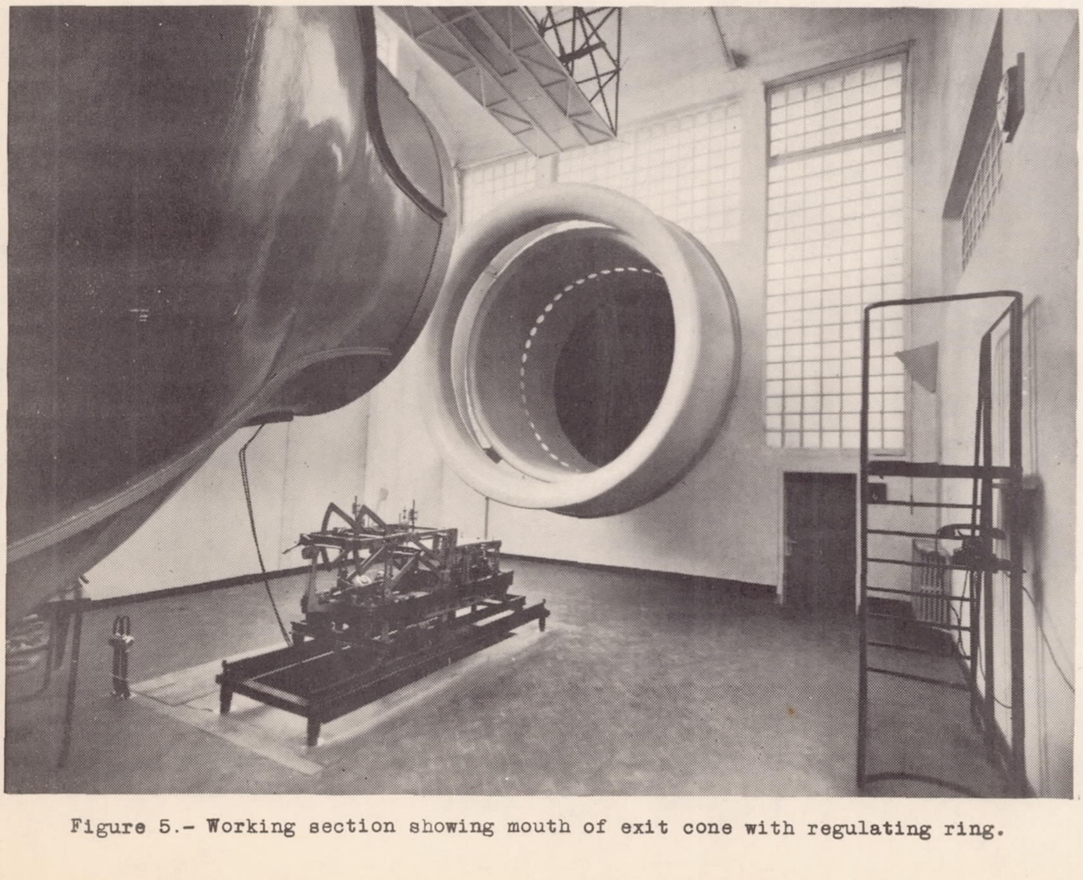

Figure 5.- Working section showing mouth of exit cone with regulating ring.

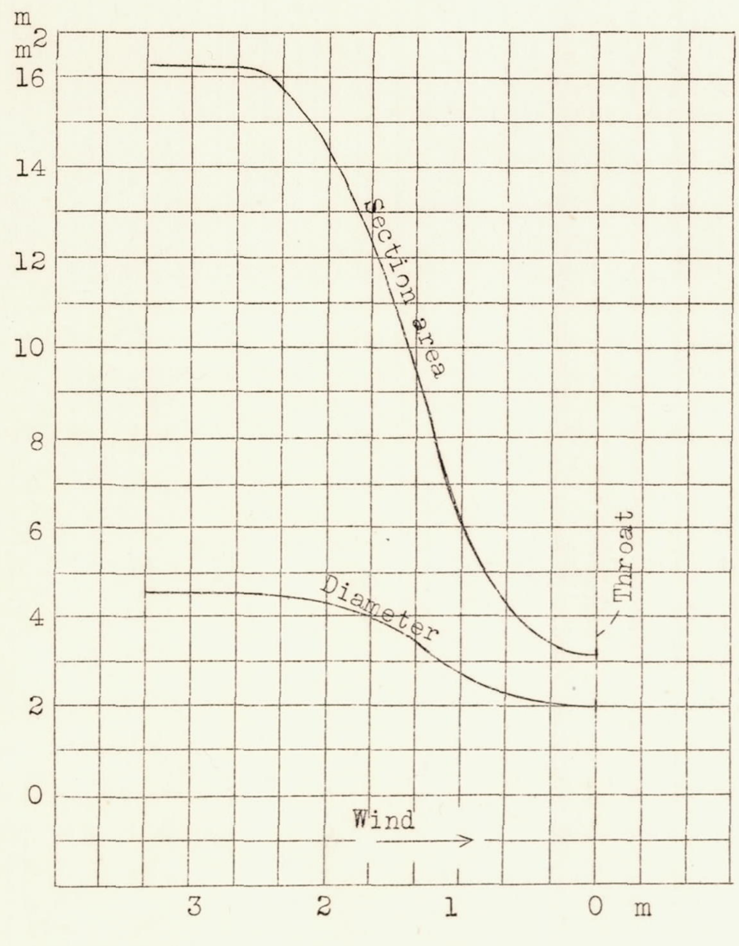

Figure 4.- Variation of diameter and area of collector.

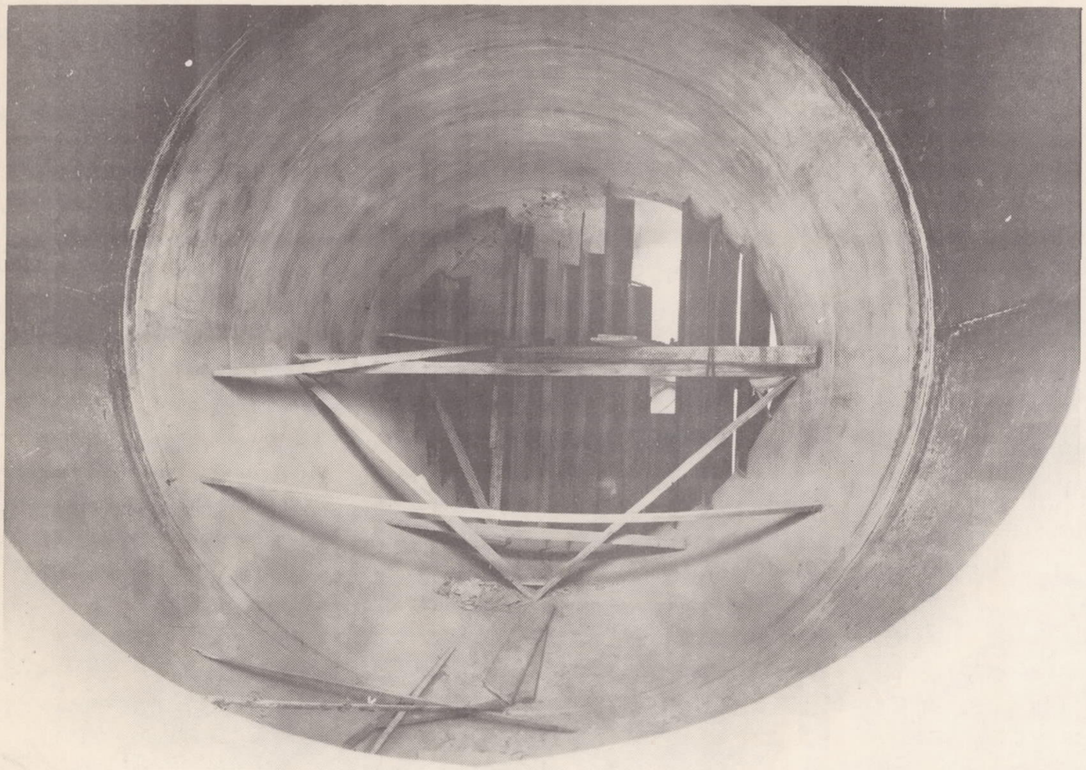

Figure 6.- Guide vanes during installation.

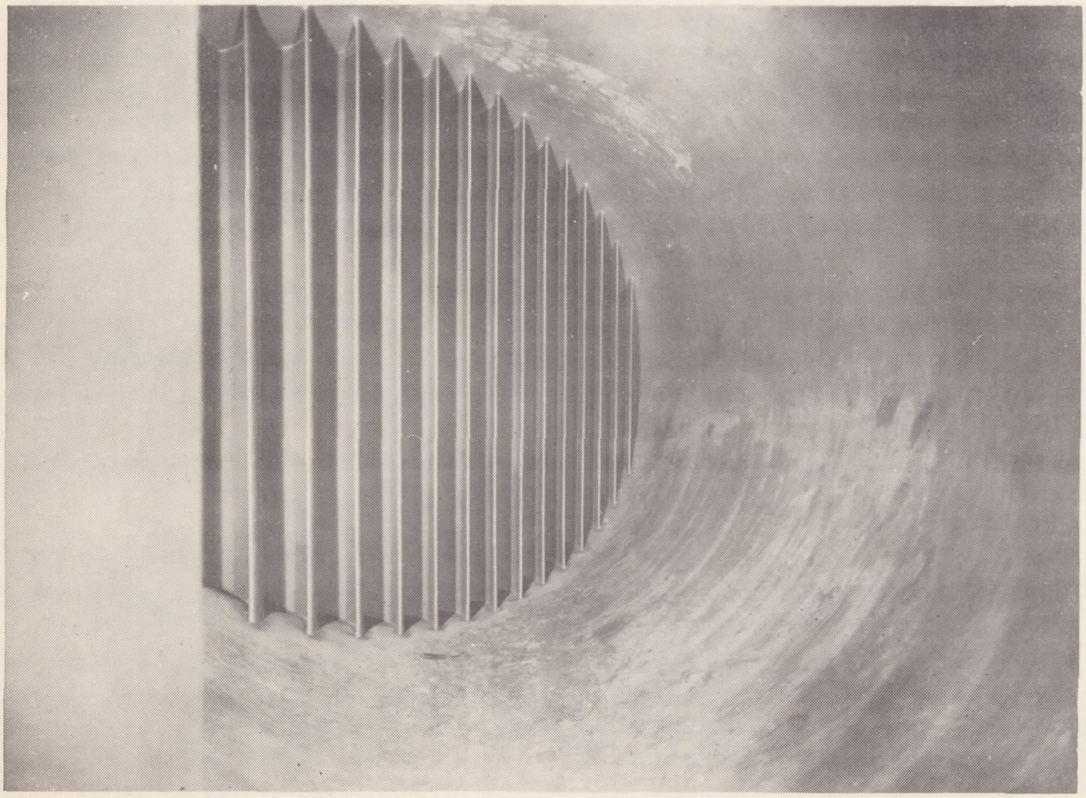

Figure 7.- Guide vanes in place.

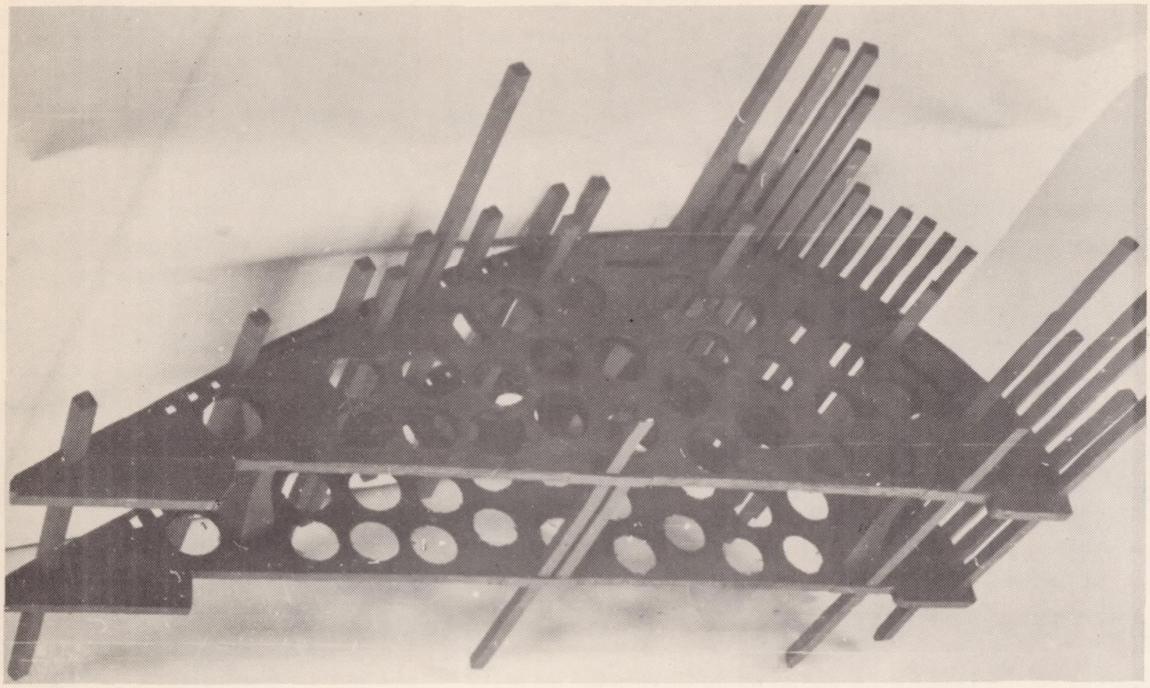

Figure 9.- Jig used to determine the intersection of the guide vanes with the inside wall of the tunnel.

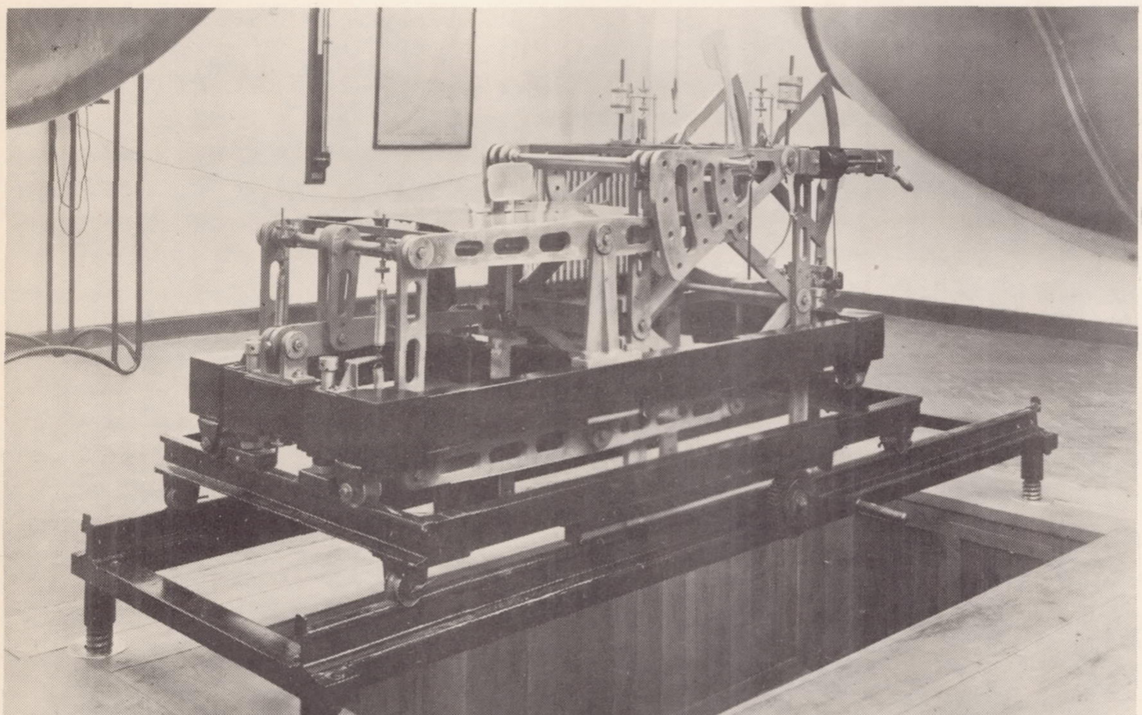

Figure 14.- Wind-tunnel balance.

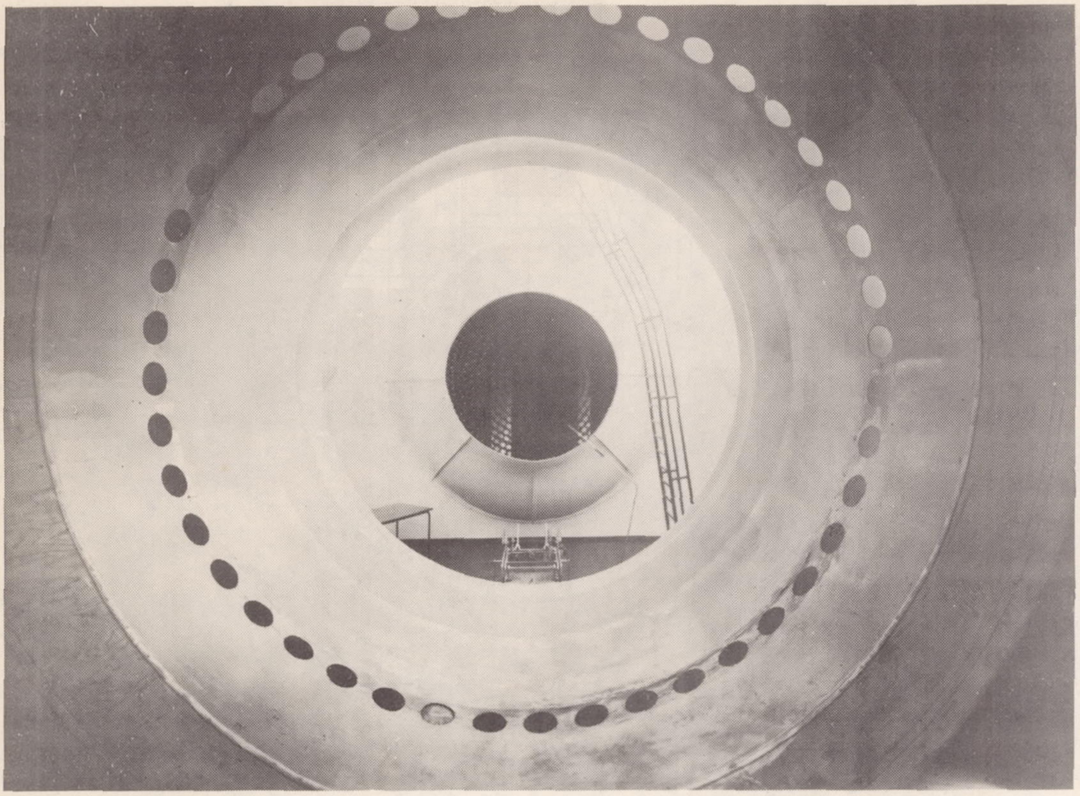

Figure 10.- Collector with straightener viewed from interior of exit cone.

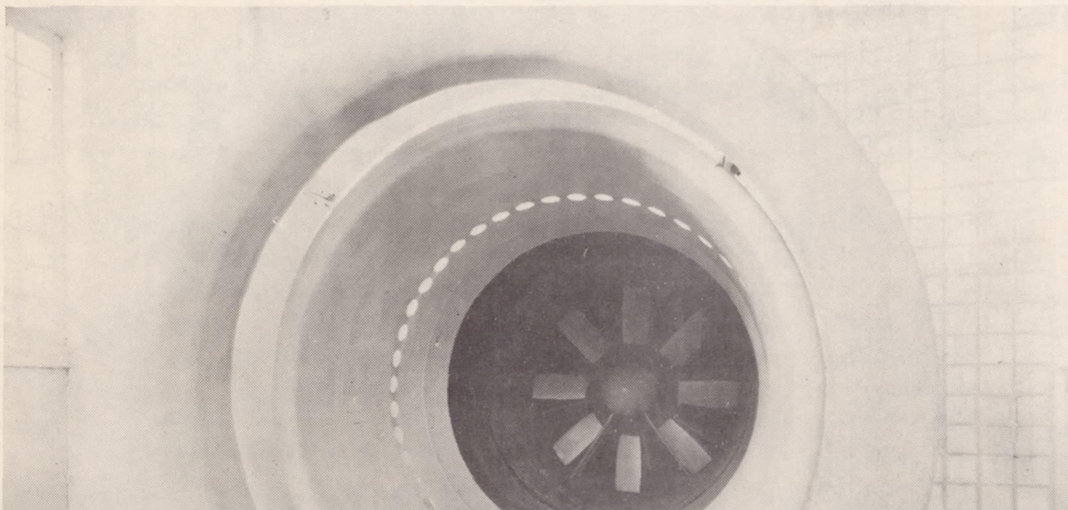

Figure 13.- Propeller assembly(2 propellers with contra-vane).

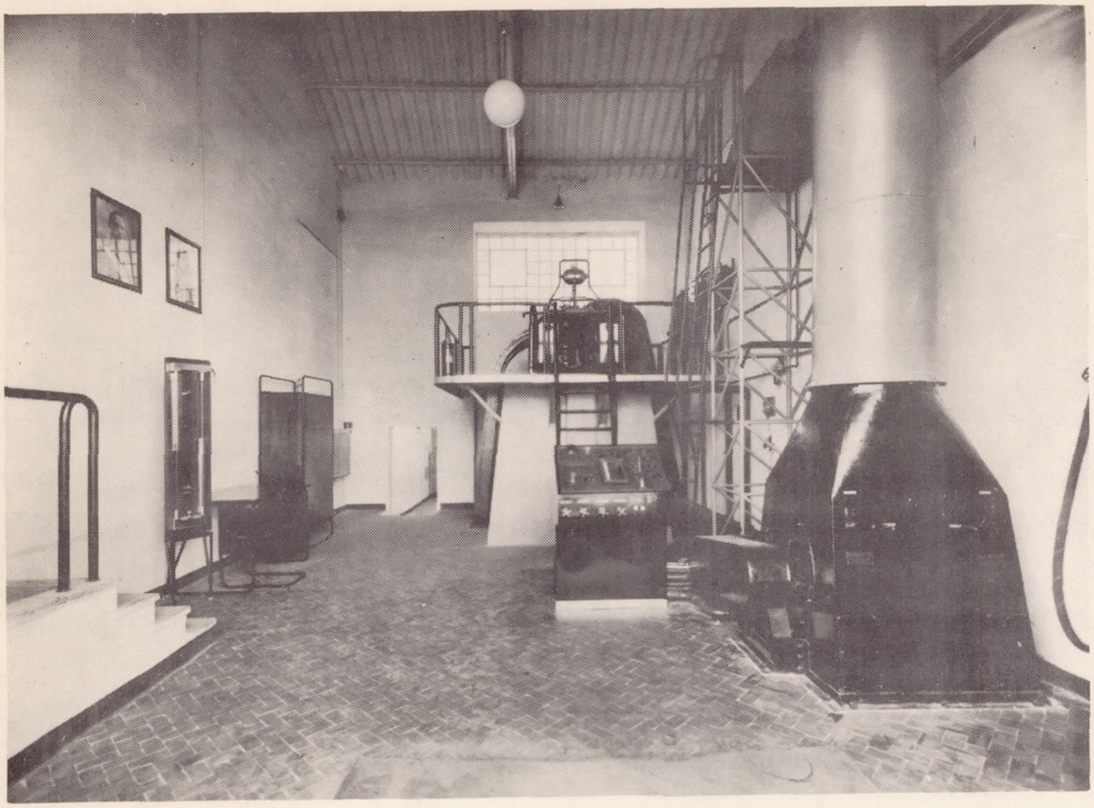

Figure 11.- Engine room.

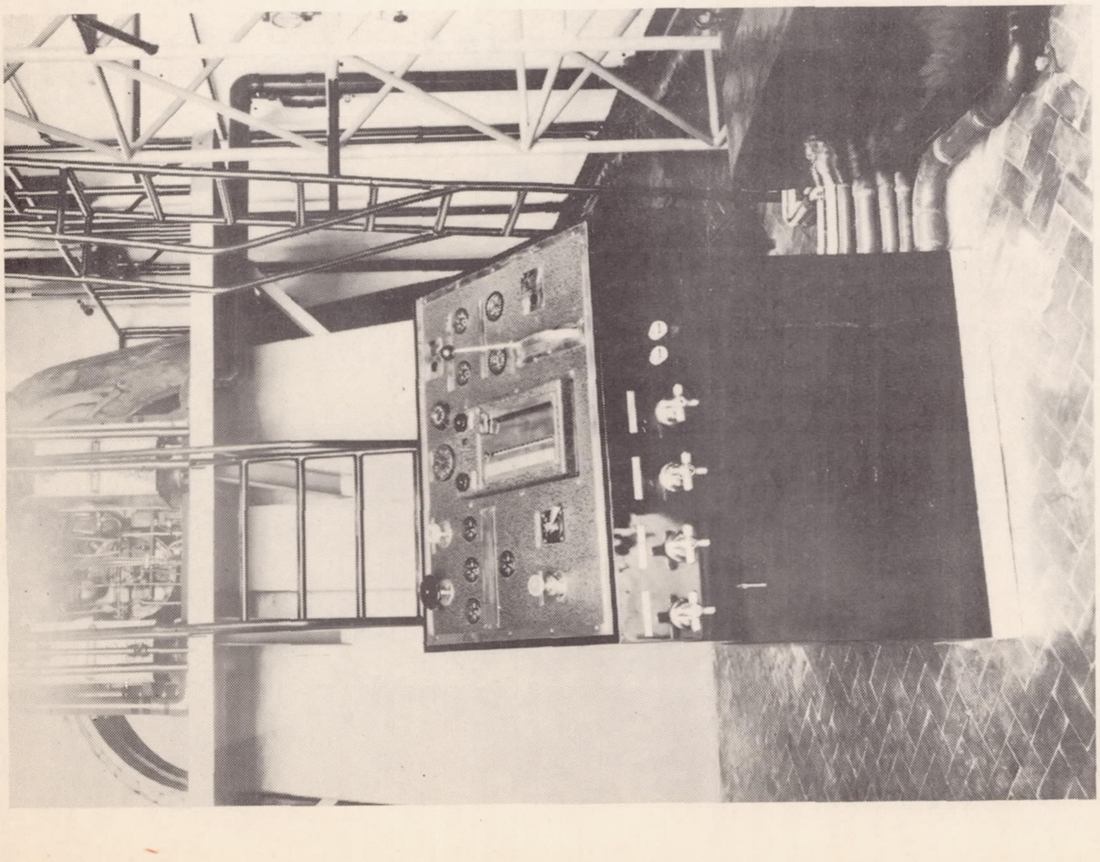

Figure 12.- Engine control panel.